A Prototype of a Non-Invasive Real-Time Beam Size and Energy Spread Monitoring System in an EPICS Environment

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Epics Collaboration Meeting

Jefferson Lab

Controls Group

- Introduction

- Synchrotron radiation and its use for beam size and energy spread monitoring

- Synchrotron Light Interferometer (SLI) at Jefferson Lab

- Conclusions

CEBAF

at

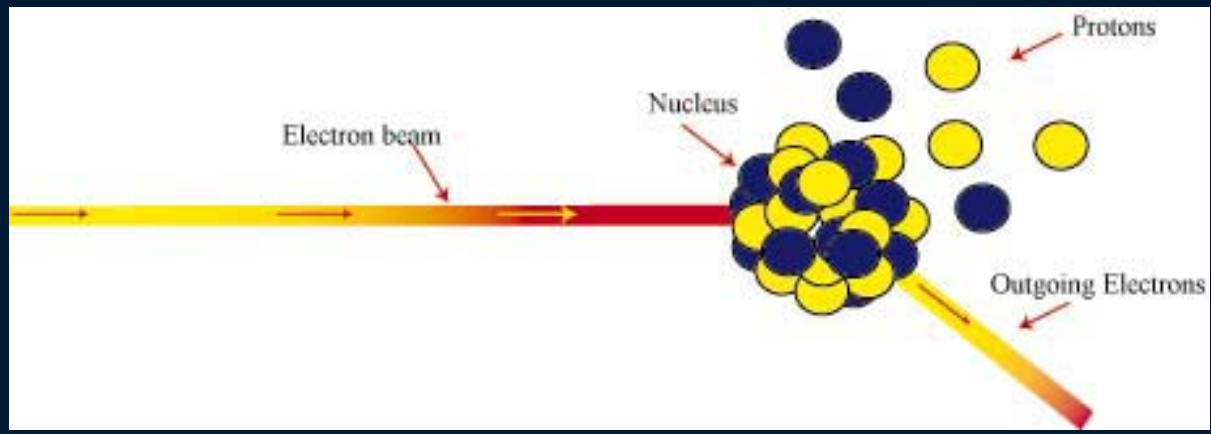
Jefferson Lab

experimental end stations

high beam quality ???

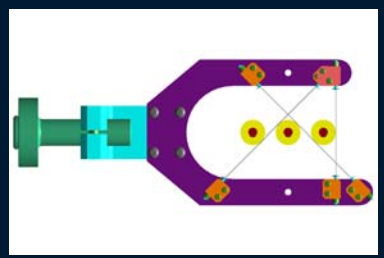
- small beam size (~30 μm on target)

- very small energy spread (~$2*10^{-5}$)

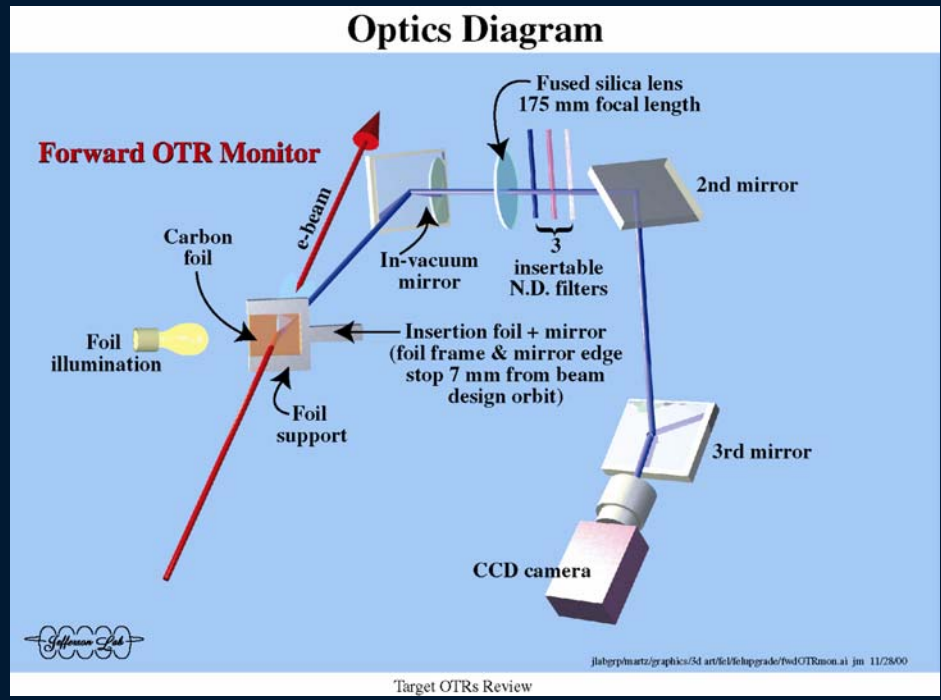


A growing number of experiments at Jefferson Lab require at least 5 GeV, 100 μA CW electron beams with continuous (real-time) energy spread monitoring.

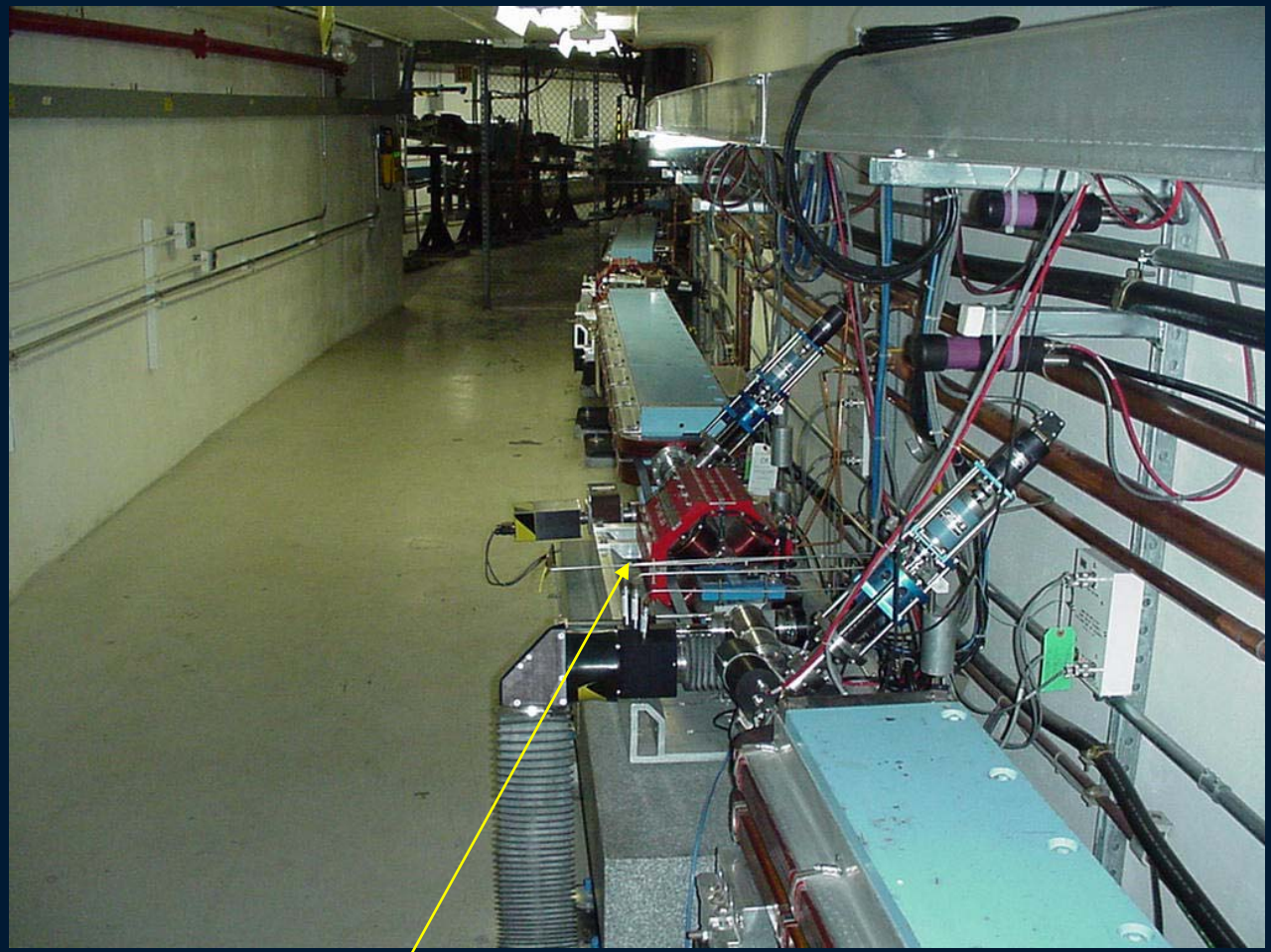
Beam size and energy spread measurement methods



wire scanners



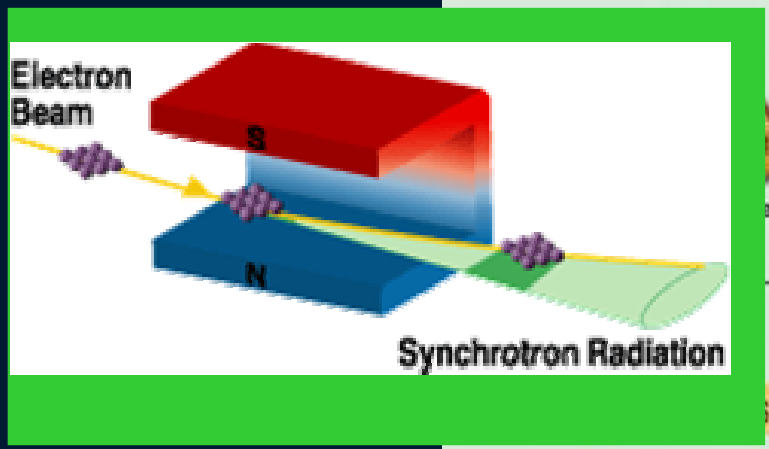
OTR

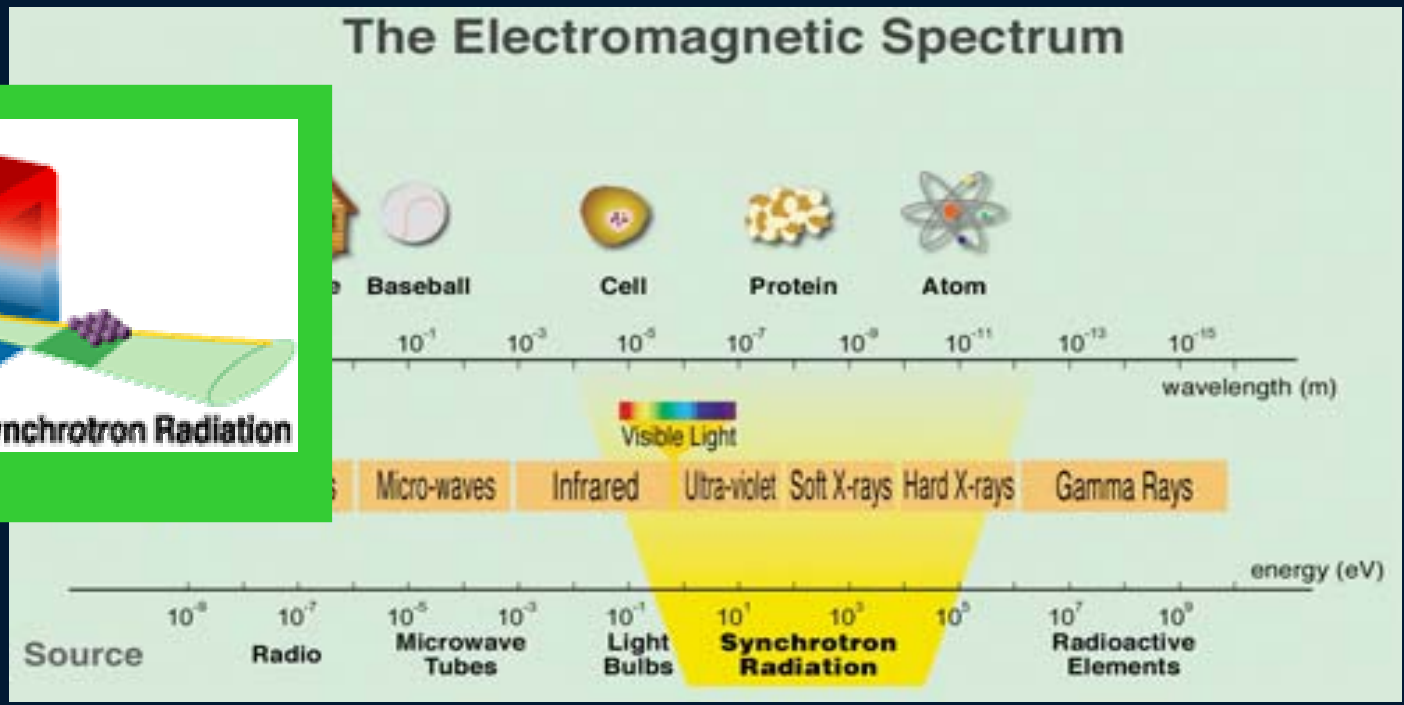


High dispersion location 3C12 ($\sigma_S < 0.08$ mm)

In high dispersion areas:

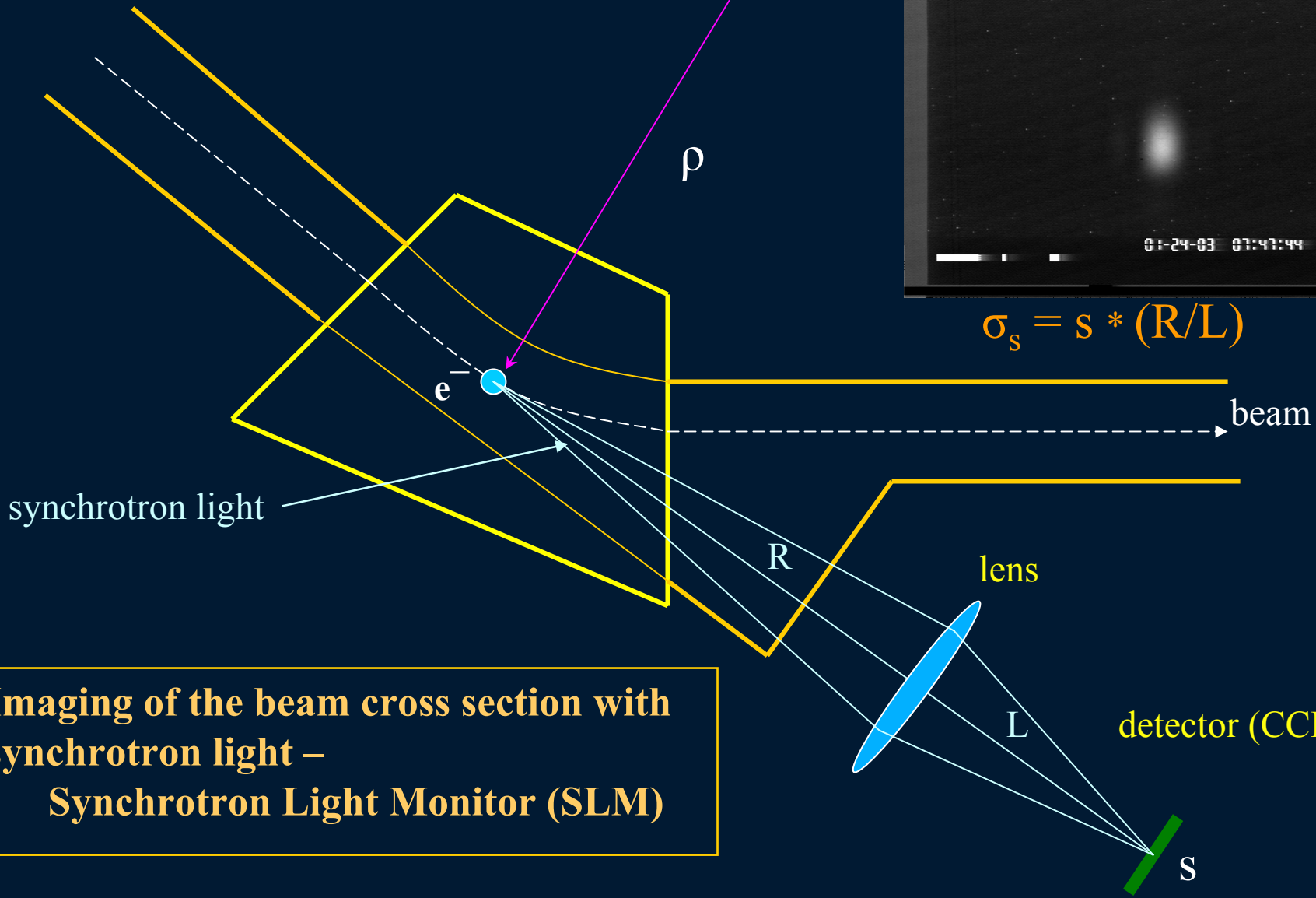
- the beam energy spread: $\sigma_E/E = \sigma_{beam}/d$
- we can relatively easily use synchrotron light to measure the beam size





The resolution of SLMs is limited !

$\sigma_s = s * (R/L)$



Imaging of the beam cross section with synchrotron light –
Synchrotron Light Monitor (SLM)

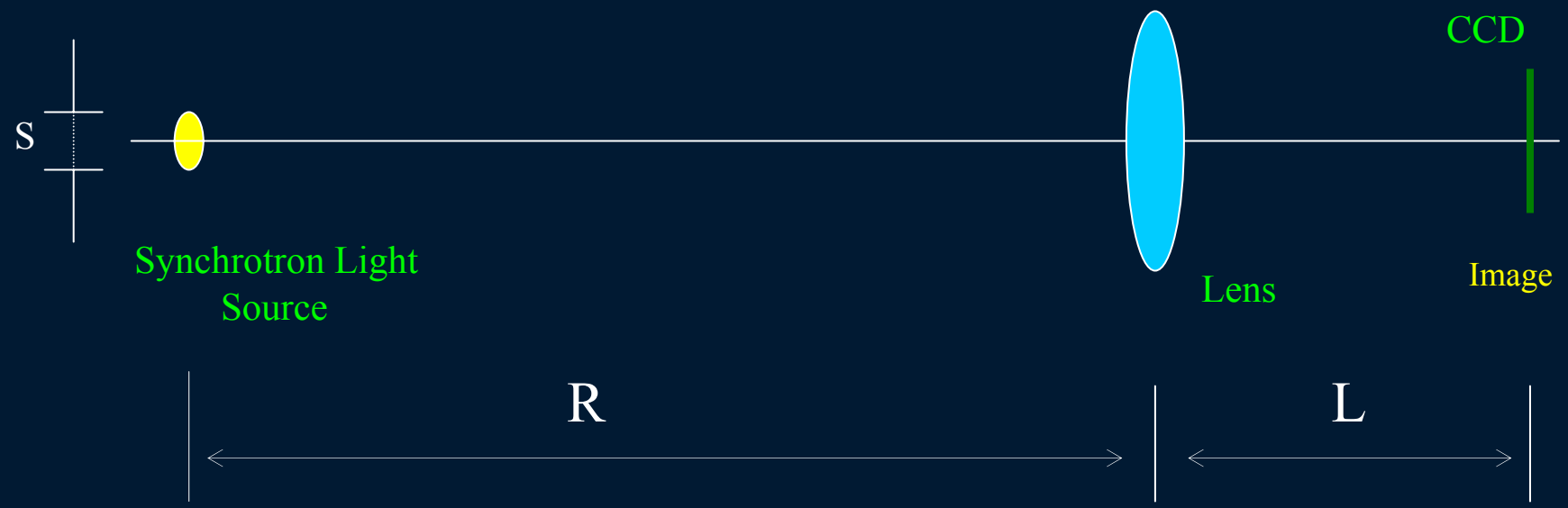
The diffraction limited resolution of synchrotron light imaging systems in the visible part of the spectrum [A.Hofmann]:

$$\sigma_S \approx 0.3\ (\lambda^2 \rho)^{1/3}$$

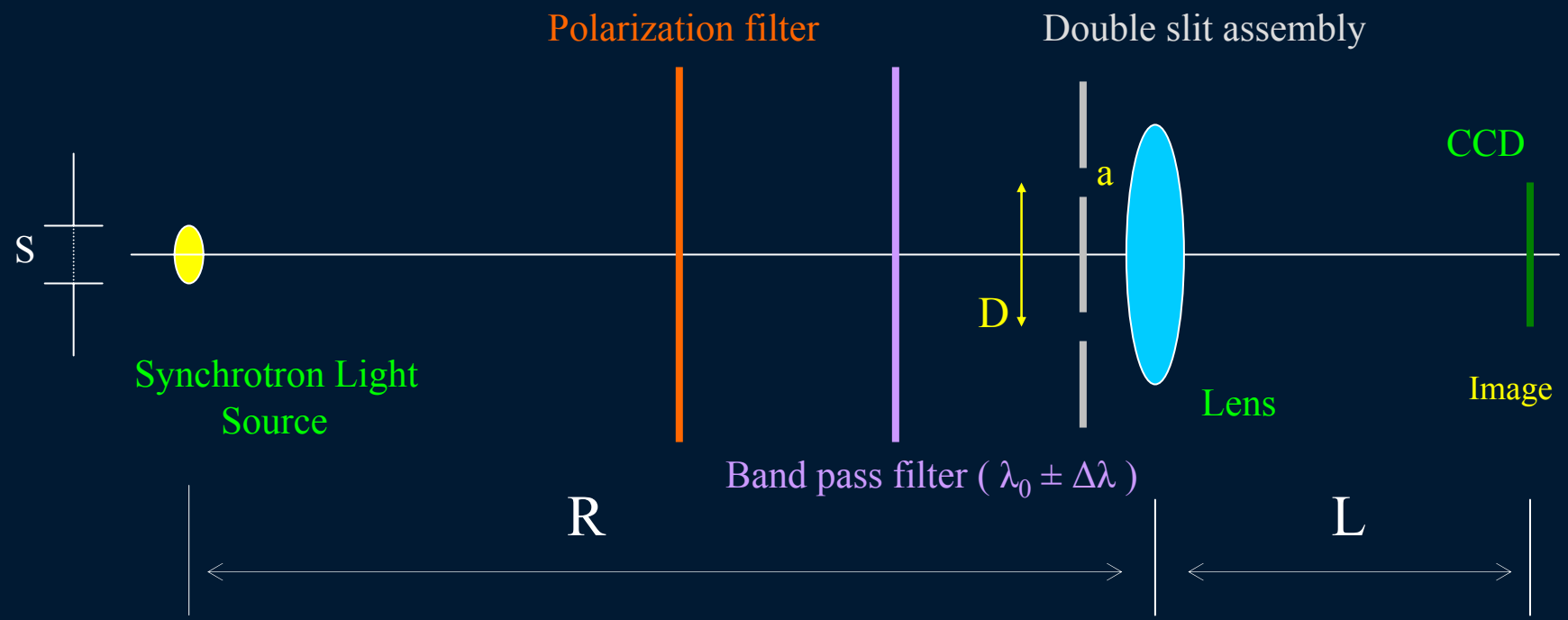
Example: $\lambda \approx 630$ nm, $\rho \approx 40$ m

$\sigma_S \approx 0.08$ mm

Synchrotron Light Monitor (SLM)

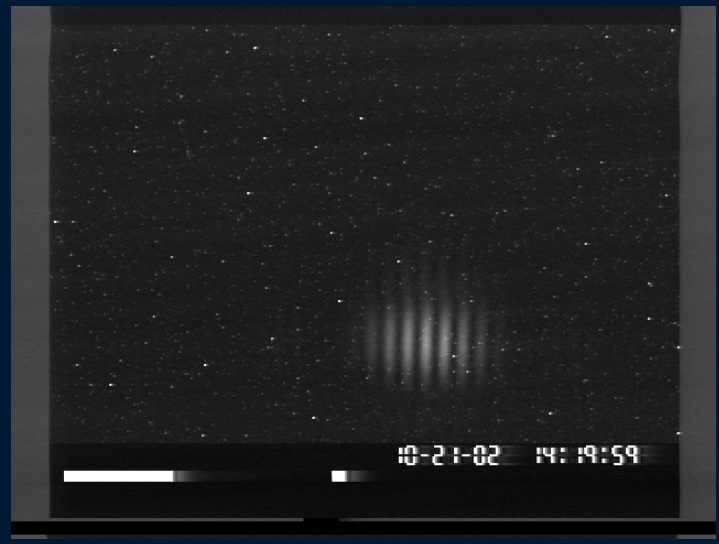


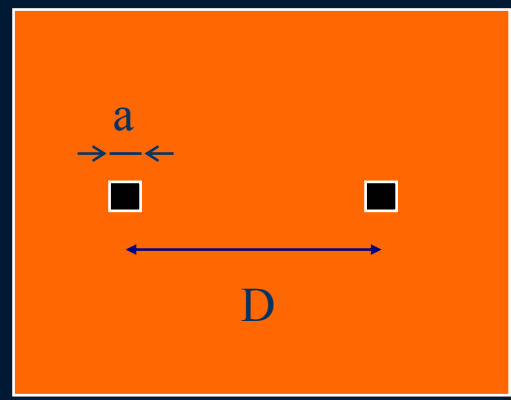
Synchrotron Light Interferometer (SLI)



SLM beam image

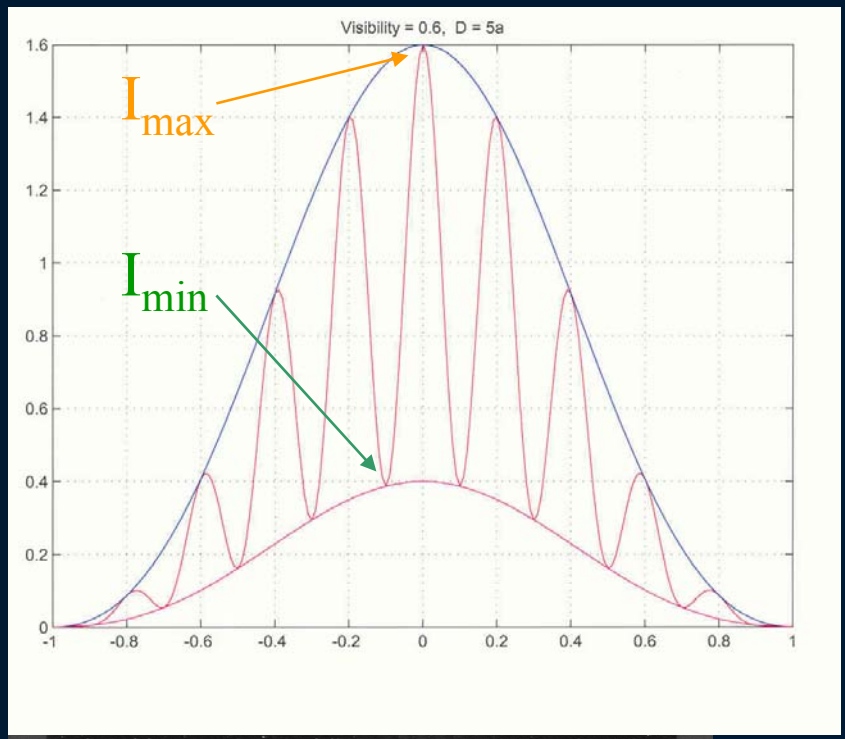
SLI interference picture



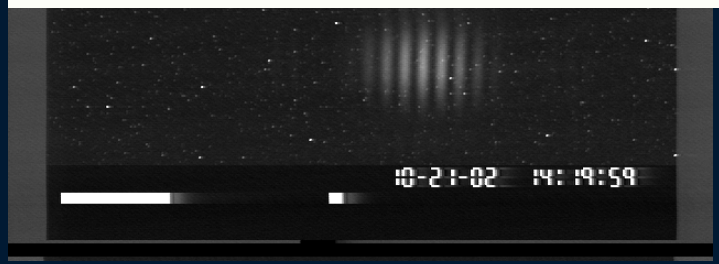


$$I(x) = I_0 \left[\frac{\sin(\alpha x)}{\alpha x} \right]^2 [\, 1 + V \cos(kDx/L) \,]$$

$$\alpha = ka/2L$$

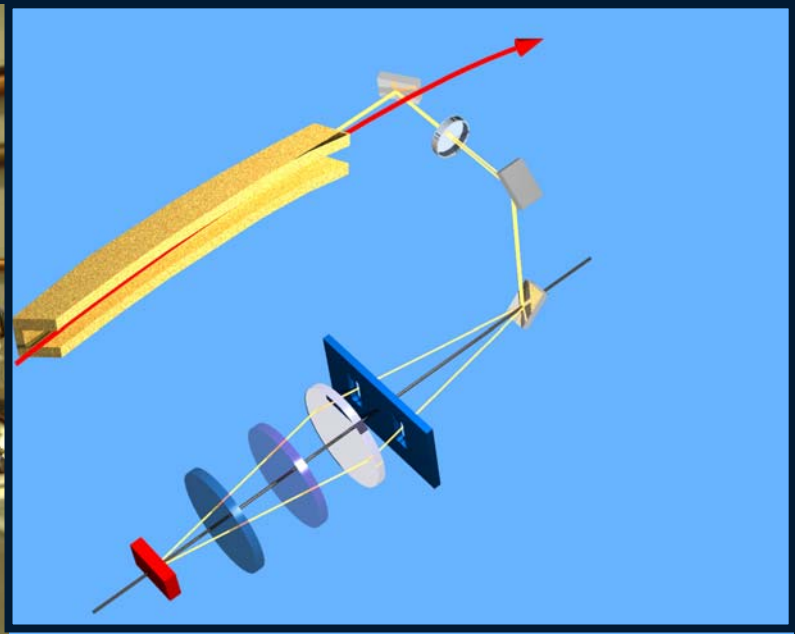


$$V = \frac{I_{max} - I_{min}}{I_{max} + I_{min}}$$



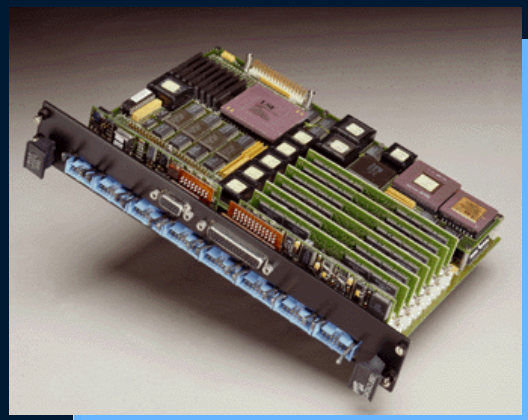
$$\sigma_{beam} = \frac{\lambda R}{\pi D} \sqrt{0.5 \ln(1/V)}$$

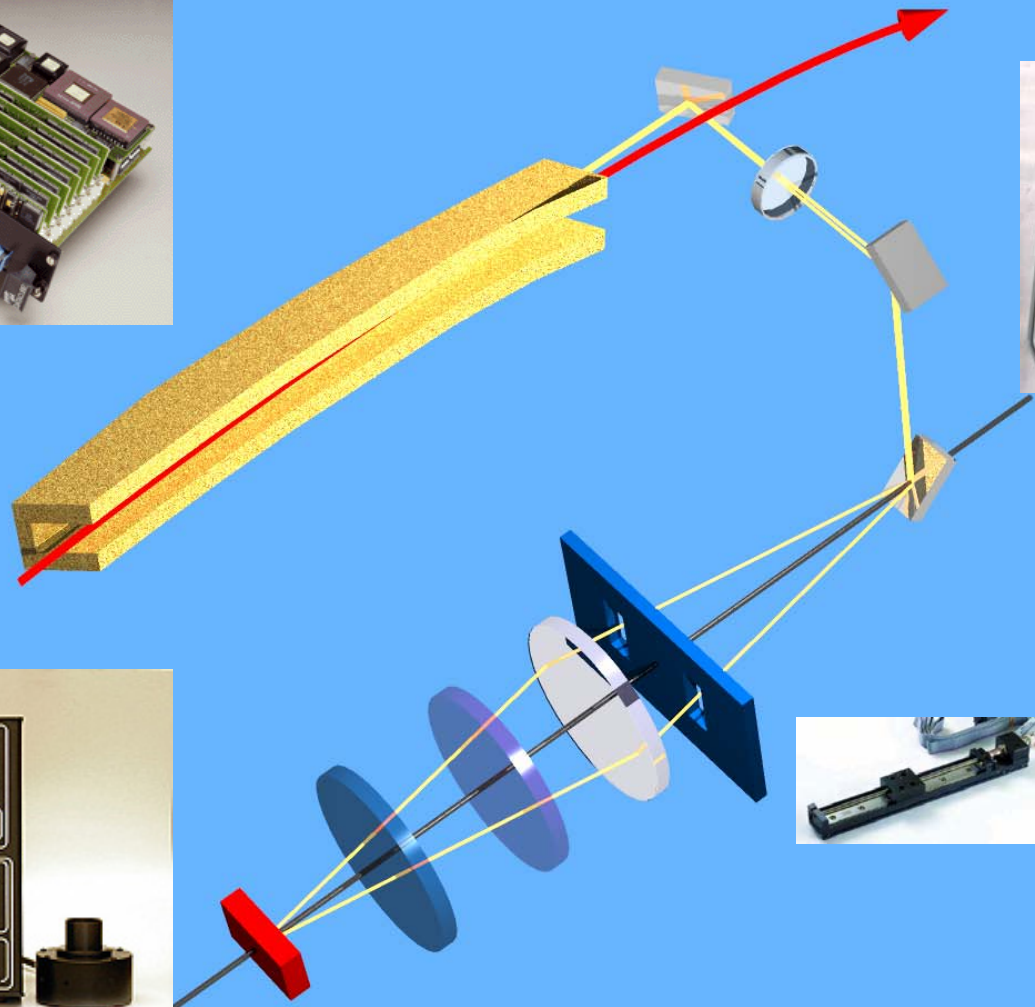
van Cittert, Zernike, Mitsuhashi



Synchrotron Light Interferometer installed at the high dispersion location 1C12

SLI Control Components





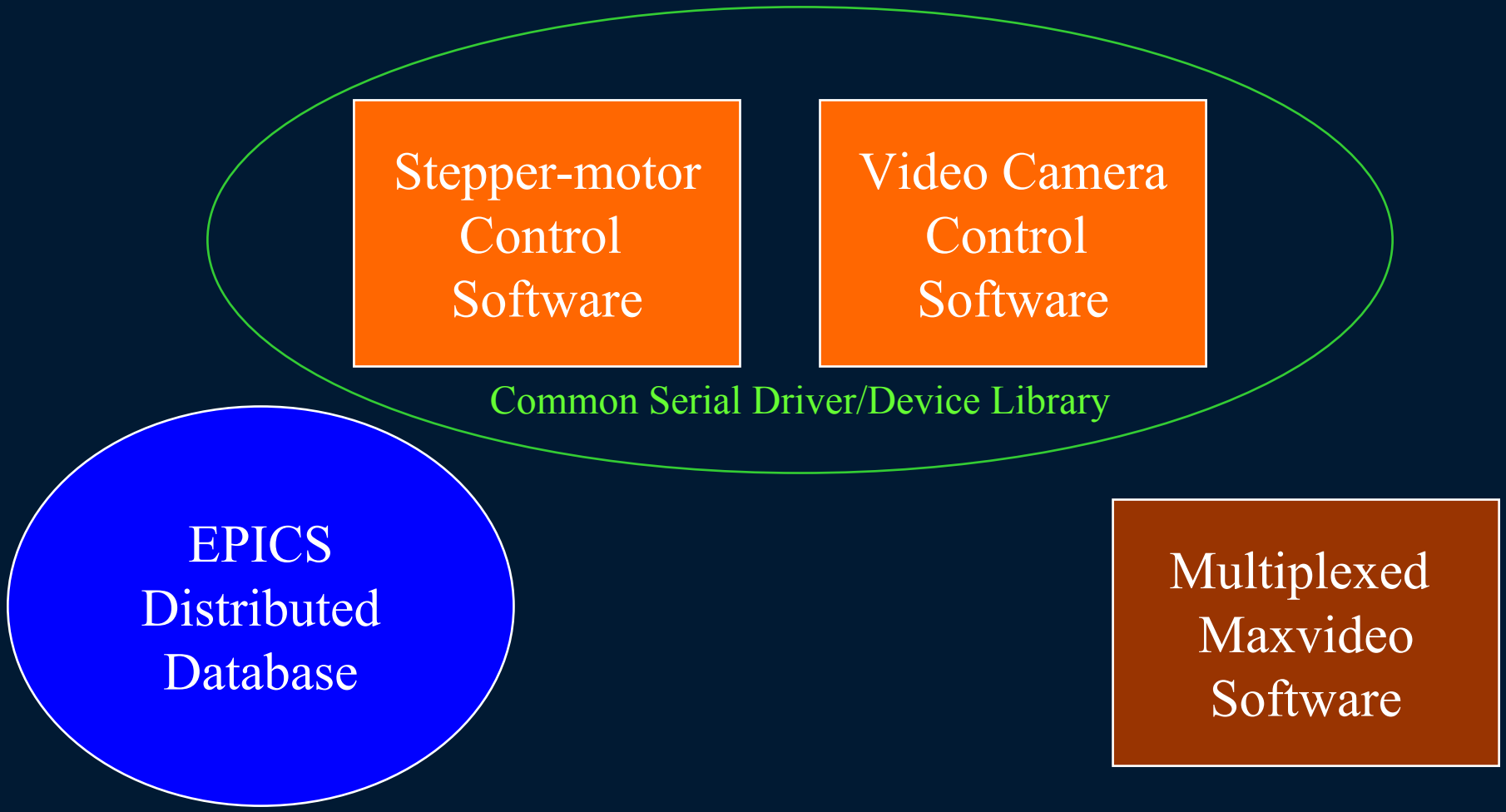

ENCODER MIKE CONTROLLER 18011
ORIEL
ORIEL Model 18011 Encoder Mike Controller


SBIG
STV
Acquire
Control
Guide
Process
Setup
Interrupt

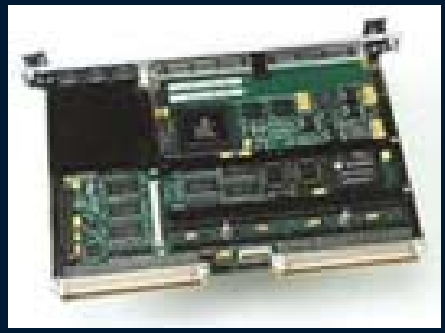

MicroMini™ Controller
National Aperture, Inc.

SLI Control and Image Processing Software

SLI Control Software



Stepper-Motor and Video Camera Control Software

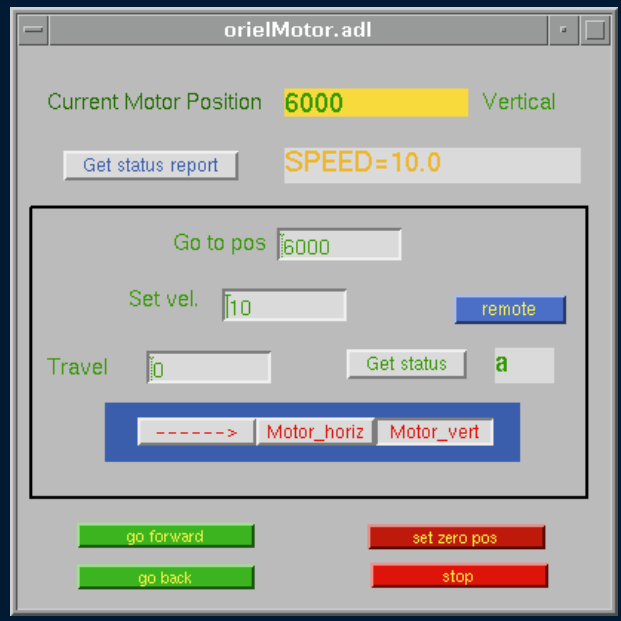


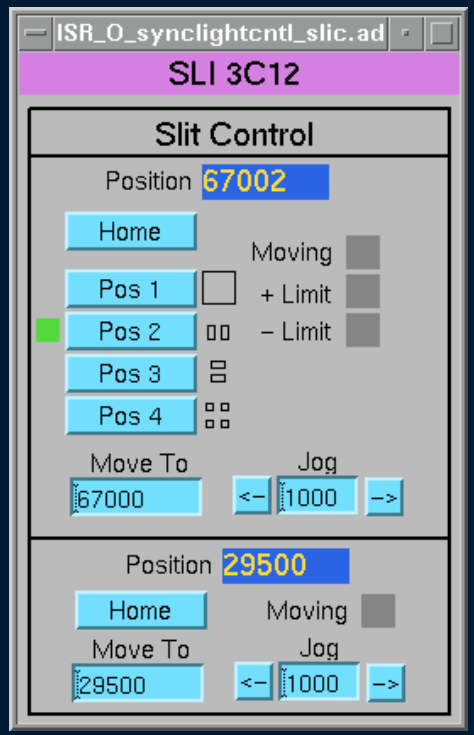
Common Serial Driver/Device Library

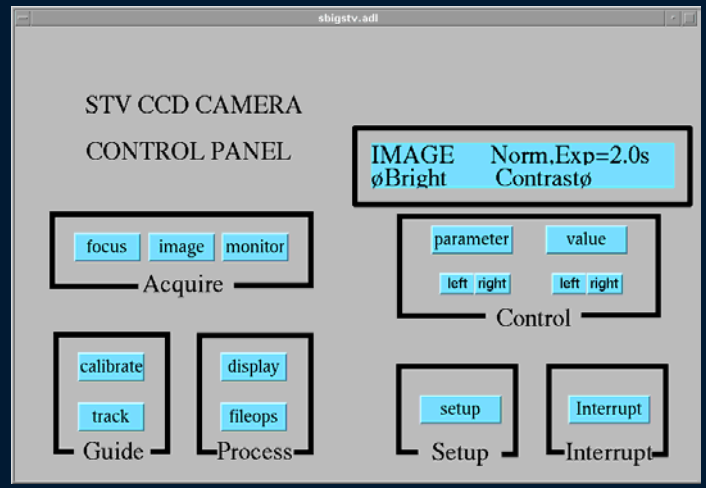
Device Configuration Handler


MicroMini™ Controller
National Aperture, Inc.


ENCODER MIKE CONTROLLER 18011
ORIEL
ORIEL Model 18011 Encoder Mike Controller

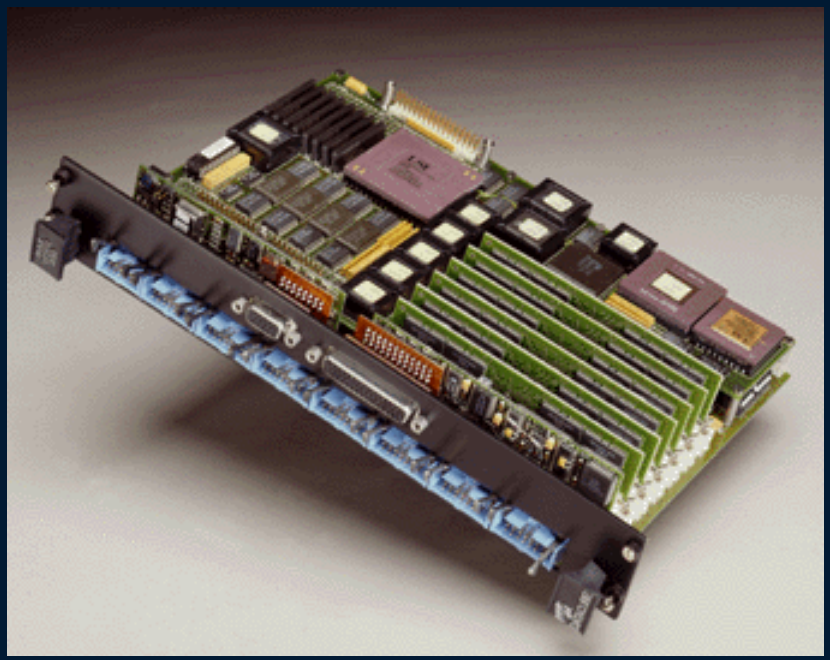

orielMotor.adl
Current Motor Position
6000
Vertical
Get status report
SPEED=10.0
Go to pos
6000
Set vel.
10
remote
Travel
0
Get status
a
------>
Motor_horiz
Motor_vert
go forward
set zero pos
go back
stop

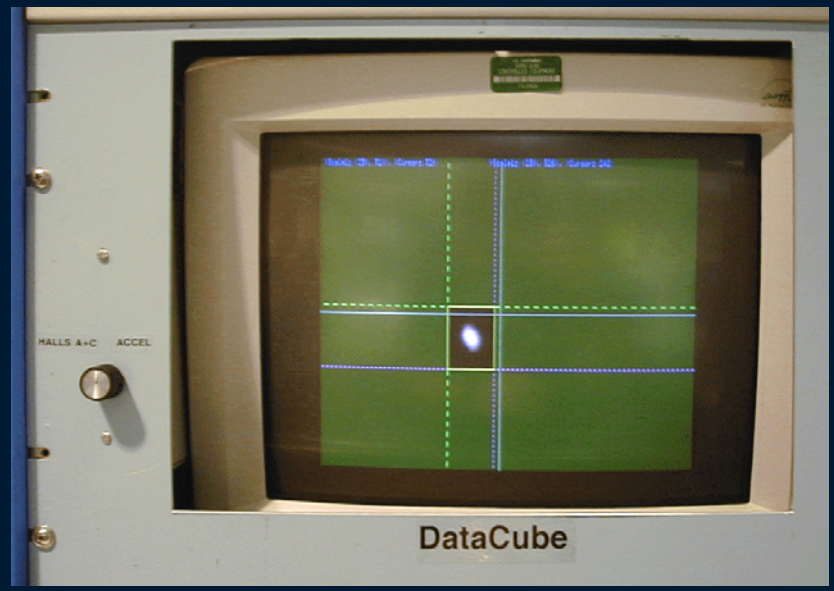

ISR_O_synclightcntl_slic.ad
SLI 3C12
Slit Control
Position
67002
Home
Moving
Pos 1
+ Limit
Pos 2
- Limit
Pos 3
Pos 4
Move To
Jog
67000
<-
1000
->
Position
29500
Home
Moving
Move To
Jog
29500
<-
1000
->


sbigstv.adl
STV CCD CAMERA
CONTROL PANEL
IMAGE
Norm,Exp=2.0s
øBright
Contrastø
focus
image
monitor
Acquire
parameter
value
left
right
left
right
Control
calibrate
track
Guide
display
fileops
Process
setup
Setup
Interrupt
Interrupt

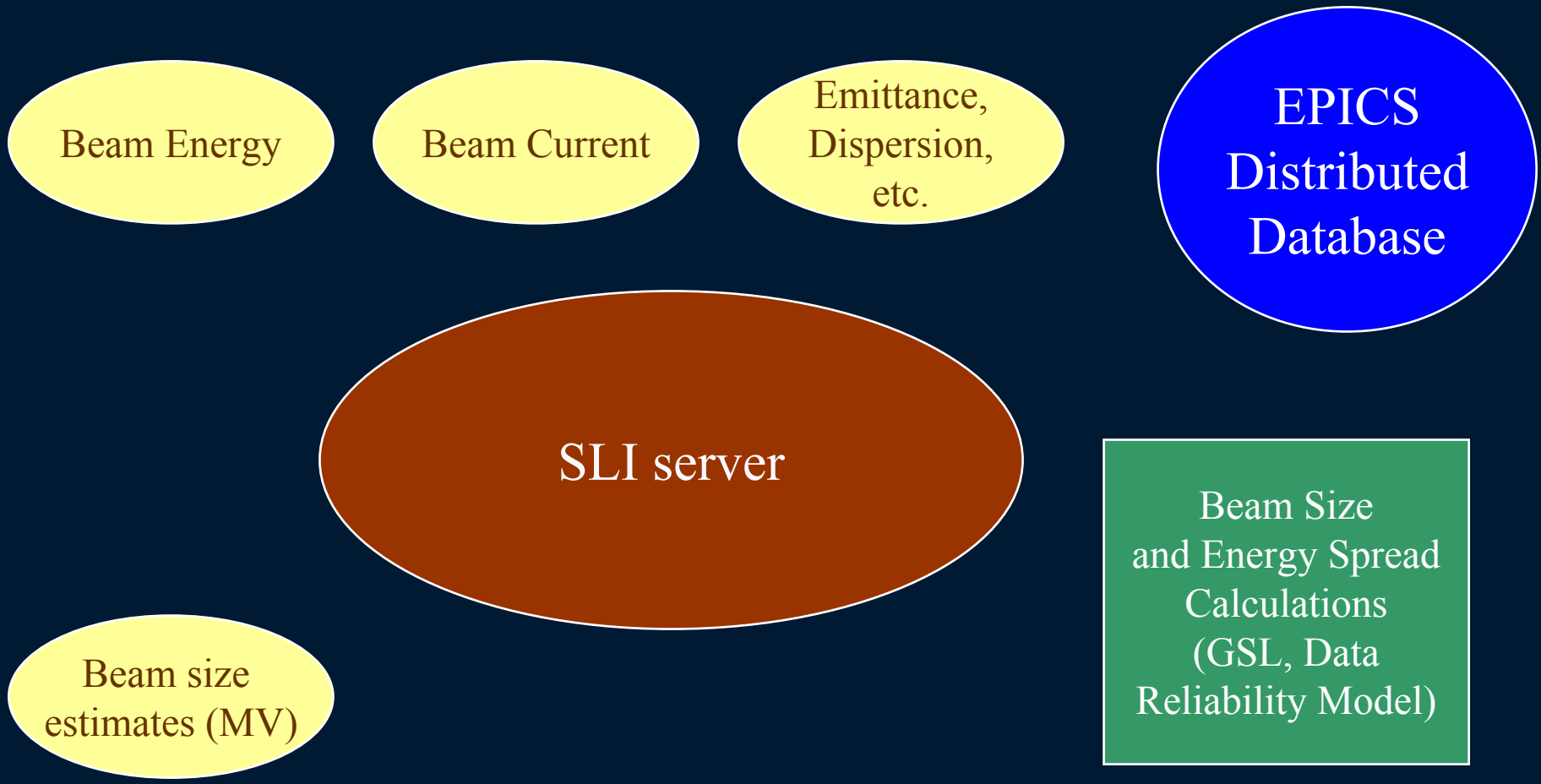

SBIG
STV

Maxvideo (MV, Datacube)





SLI Image Processing Software



SLI server

Main SLI Control Screen

DAQ_C_1C12_slia.adl

Hall A Synchrotron Light Interferometer (1C12) Status and Control

HELP

SLI Components

Control Status

Video_Camera IMAGE Norm,Exp=1.5s

OK

Diffraction_Slits 3mmSquare

161 Maxvideo

SLI Server Heartbeat

video disabled enabled

Calibration screen HALL A

Advanced Digital Image

LUT1 Mode Subtract

DataValid Beam current 119.61 mkA

LUT1 Threshold 0

Yes

Acquire Gain 0.815 0.8

Masks enable mask enable disp mask

X1: 108 Y1: 91

X2: 277 Y2: 282

Number of saturated pixels

MASK OUTSIDE

0

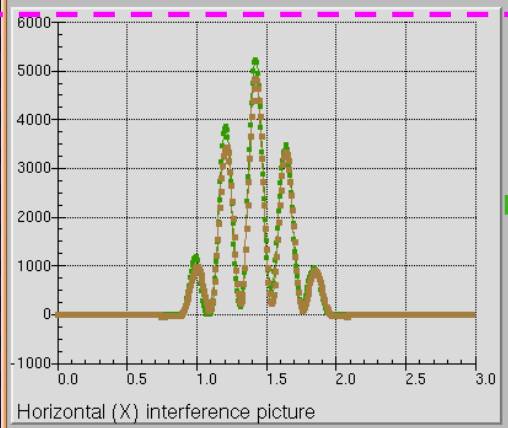
Horizontal Plane (X direction)

Visual Data (rough estimates)

Image Position on CCD (4.8 x 3.6 mm) 1.424

Beam Size 0.148 mm

Energy Spread 1.854 10**(−5)



Horizontal (X) interference picture

Model Data

Beam Size 0.151 +−0.007 mm

Energy Spread 1.884 +−0.087 10**(−5)

OK

Error sum 29.938

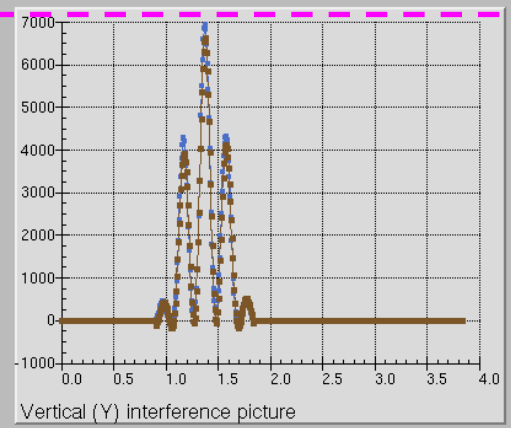
Reliability 0.194

Vertical Plane (Y direction)

Visual Data (rough estimates)

Image Position on CCD (4.8 x 3.6 mm) 1.375

Beam Size 0.086 mm



Vertical (Y) interference picture

Model Data

Beam Size 0.096 +−0.011 mm

OK

Error sum 18.861

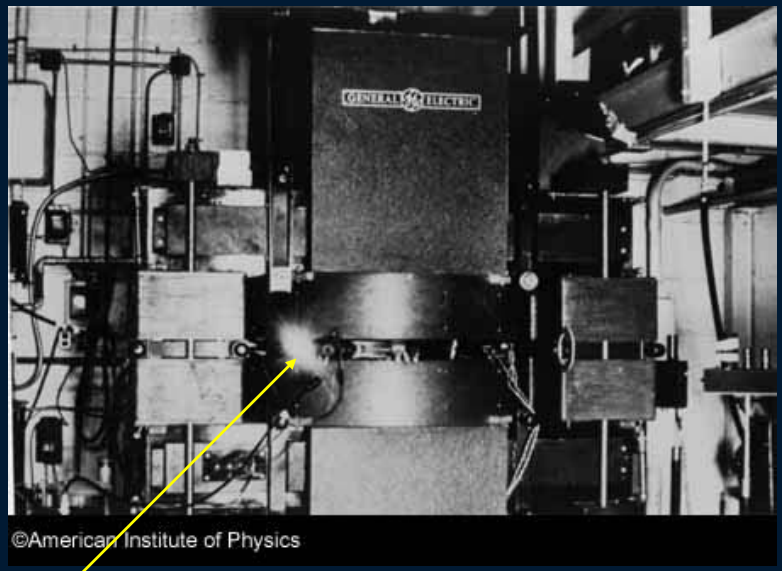
Reliability 0.335

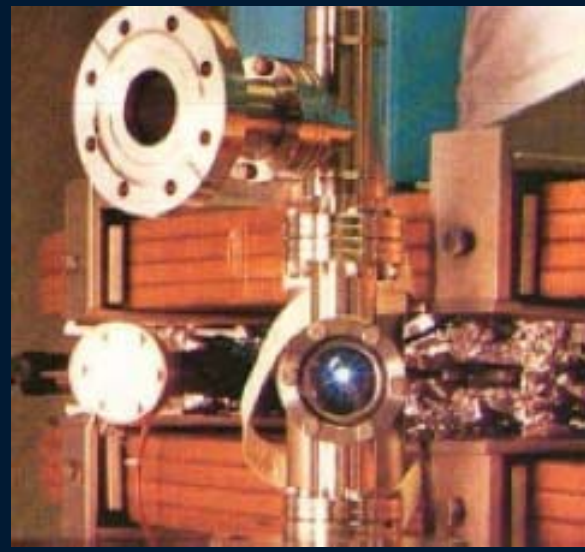
Conclusions:

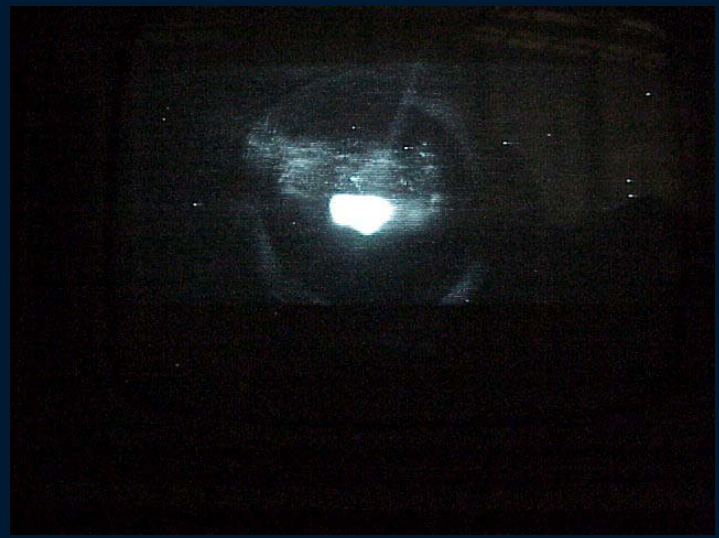
- We have built a prototype of a real-time non-invasive beam size and energy spread monitoring system (SLI) that has a very high resolution

- We have designed and created control and image processing software in an EPICS environment that can easily be used at all collaboration Institutes

Some SLI pictures


GENERAL ELECTRIC
©American Institute of Physics



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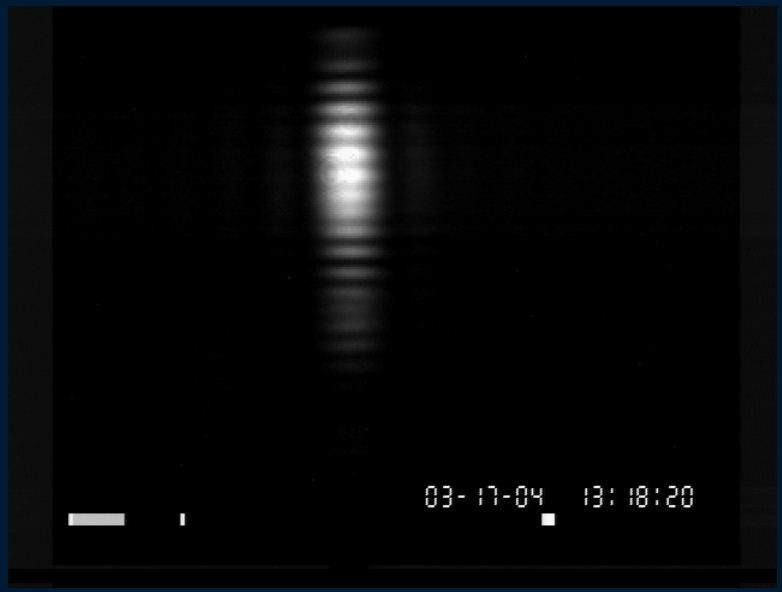
01-07-03 11:18:23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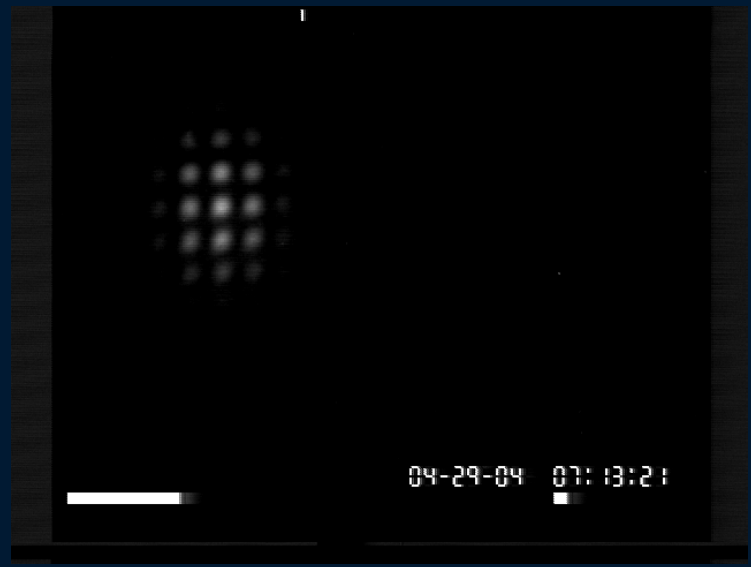
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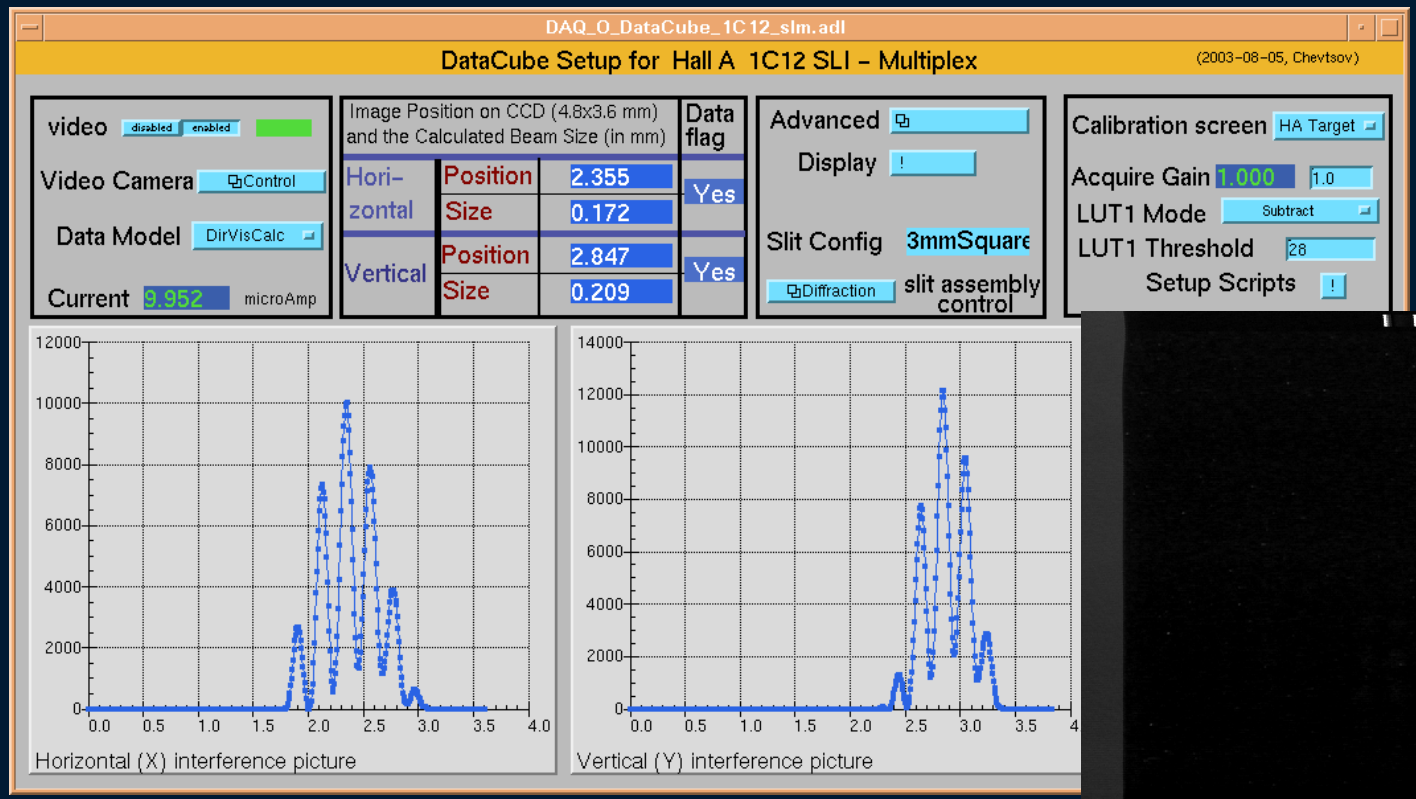

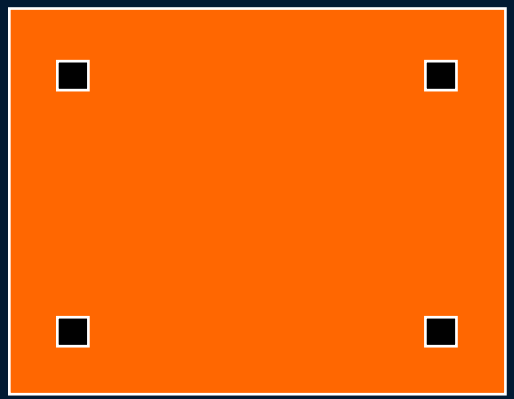

$$I(x,y) = I(x) \cdot I(y)$$

E N D